Appendix I

Climate Change and Its Impacts on New England: A White Paper

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When people think of the climate in New England they think either of crisp, clear fall days enhancing the spectacularly colorful foliage of maple, birch and hickory, sunny summer days and cool starry evenings, or pristine winter snowscapes, with snug cabins and bustling ski slopes. Those of us who live in the New England/upstate New York region, also know that the weather can be highly variable ("...if you don't like the weather, just wait a few minutes...") and unpredictable ("...last year, summer was on July 5th..."). For us, weather (day-to-day factors such as temperature, precipitation and cloud cover) is thought of as highly variable, while climate (the longer-term weather patterns characterizing an area, such as temperate or tropical climates) is considered to be more stable. However, we hear more and more about a changing climate, and most of us are not sure what climate change is or if it is something that we should really be concerned about.

As we begin to look at climate change issues and their potential impacts on the New England and upstate New York region, it is important to note that the term "climate" can refer to both the physical climate and the chemical climate. The physical climate includes variables such as temperature, precipitation patterns, and storm patterns which characterize an area, while the chemical climate includes variations in the chemical make-up of the atmosphere and precipitation. Increasing severity of storms or rising temperatures would be an example of physical climate changes, while increasing levels of ground-level ozone (a form of air pollution or smog) or acidity of rain would be examples of chemical climate changes.

Climate change may be vague and/or misunderstood by residents of the northeast region who are not specialists in this field. A number of reasons for this phenomenon are highlighted below.

- One perception could be that "climate change involves global processes that are poorly understood, and are largely beyond our control, at least at the local or regional level."
- The problems associated with climate change may be seen by the public as somehow involving tropical deforestation or ozone depletion in the Antarctic and Arctic regions, and are not considered as relevant or important to New England. Whereas climate change issues are much broader and more complex than deforestation and ozone depletion. Additionally, climate patterns are affected by the New England region and our actions within this region can have effects on the regional and global climate.
- Climate change problems are seen as very complicated and may be considered to be too difficult to be easily understood by the non-scientist. Northeastern residents, therefore, may not take an interest in the current issues and concerns of climate change.
- It is likely that even if people do recognize the problems associated with climate change that these problems are not of immediate concern. Yet, scientists are already beginning to see the signs of climate change which may be directly affecting our environment and way-of-life. We should look at these issues now and not put them off for future consideration because it may be to late to affect positive mitigation strategies.
- People who observe the reports by scientists on climate change issues may be confused by these reports and adopt a view that climate change specialists can't agree on what is happening. This may send the message that they shouldn't worry about climate change.
- Finally, one of the biggest problems getting people interested and concerned about issues related to climate change may have to deal with the transfer of misinformation on the subject. This is a two-pronged problem which involves the media's portrayal of the issues and scientists' ability to explain to non-scientists their findings. Information in the form of newspaper articles, radio and television coverage, and interpretations of

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scientific papers and reports are often incorrect. This misinformation confuses the issues of climate change, making it harder for people to understand the impacts of phenomena such as the greenhouse effect and global warming to the New England/upstate New York region.

This white paper attempts to clarify some of these misunderstandings as well as present a select set of climate change issues which may be important to the New England/upstate New York region. This paper does not attempt to address all of the possible issues. Additionally, it does not contend to answer these complex issues. The idea is to get the reader thinking about these issues and others which may be important from their perspective, in preparation for the September Workshop. One of the goals of the workshop will be to help educate the "stakeholders" on the current understanding of climate change in the northeastern United States. A second goal is to tap into the expertise of stakeholders, in a working group format, in order to help policy makers and scientists determine the importance of climate change issues for our region.

The following discussion addresses some issues and provides examples of potential climate change problems for the region.

IS THE GREENHOUSE EFFECT REAL?

Yes, the greenhouse effect is real, and in fact, essential for life as we know it on our planet. Many of the gases in our atmosphere (including water vapor, ozone, nitrogen and carbon dioxide) allow sunlight to pass through, but once the sunlight interacts with the Earth's surface, the resulting heat released is retained, resulting in a climate conducive to the maintenance of life. The presence of these gases in our atmosphere makes the Earth a living planet. Compare the Earth and its atmosphere with the moon: both are approximately the same distance from the sun, but there the similarity ends. What a difference a few gases make! Human activities, however, have resulted in a significant increase in some of these and other gases in our atmosphere. The growing concern voiced regarding future climate change relates to this ***enhanced*** greenhouse effect.

From the beginning of the Industrial Revolution (in the 1870's), human activities have increased the introduction of greenhouse gases such as carbon dioxide (CO_2), water vapor (H_2O), methane (CH_4), ozone (O_3), chlorofluorocarbons (CFCs), and nitrous oxide (N_2O) into the atmosphere. All of these gases trap heat. The overall increases in CO_2 over

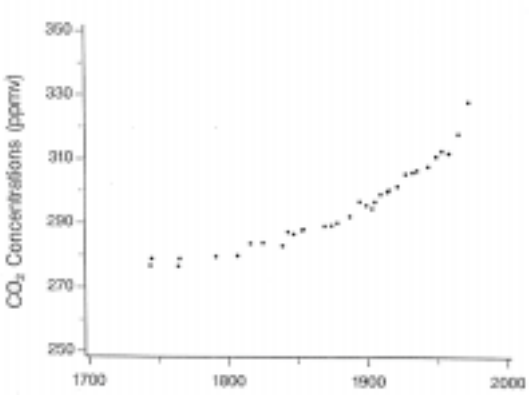

Figure 1. Atmospheric carbon dioxide concentrations derived from ice core data show that this greenhouse gas has steadily increased since the mid-1700s. This phenomenon has been confirmed by independent researchers around the world. And, many of the trends seen in the peaks and valleys of the data can be correlated to specific global or regional events.

time (1750 - present) is shown in Figure 1. The detailed studies of ice core records from glaciers in Greenland and the Antarctic shows that climate change is normal and closely correlated with changes in carbon dioxide and methane in the atmosphere. Dramatic climate change has occurred in the past, even in the absence of human activities, and in all cases, warming is associated with high levels of greenhouse gases, while cooling is characterized by decreased levels of these gases.

A primary question is: how much are humans influencing the climate compared to the natural climate variability? And more importantly, what will this mean for our well being and the well being of the current global ecosystems. Research has shown that the observed increases in greenhouse gas concentrations are human-influenced. The time scale of the human-induced climate change and the magnitude of potential impacts are we should be concerned about.

WHAT ABOUT GLOBAL WARMING?

While large fluctuations in both greenhouse gases in the atmosphere and climate change are clearly normal for our planet, the 1997 levels of atmospheric CO_2 are the highest they have been for the last 160,000 years (based on the ice core record). There is no debate about this! Scientists agree that greenhouse gas levels are increasing in the Earth's atmosphere and there is also consensus among scientists that at least part of this increase is a result of human activity. What is being "hotly" debated at present, is what effect this ***enhanced*** greenhouse effect will have in terms of a warming of the atmosphere.

The ice core records show a direct correlation between CO_2 levels in the atmosphere and global temperature. If the past ice core record is used as an indication of what will happen in the future. If CO_2 levels continue at the present rate of increase, global temperatures can be predicted to rise 2-5ºC (4-9ºF) by 2050. Temperatures in the Arctic are predicted to rise twice as fast—in fact, temperatures there have alread risen by 2ºC in the past 30 years.

In 1995, an international panel of over 2,000 scientists—the Intergovernmental Panel on Climate Change (IPCC)—stated that the observed warming trend seen over the past decade is connected with the increasing levels of greenhouse gases in the atmosphere. This IPCC Report represents the first broad scientific consensus that the ***enhanced*** greenhouse effect has led to increased temperatures over the past century. It is important to note that even if overall warming is seen, the temperature trends observed at the local level will continue to be highly variable. Exactly what this will mean for our region is uncertain and needs more attention.

Doesn't climate change involve global processes that are poorly understood, and largely beyond our control, at least at the local or regional level?

Climate change is a global phenomenon and is based on properties of the atmosphere such as temperature and precipitation. But, climate has many regional action centers. Some are very large such as the El Niño-Southern Oscillation (ENSO) centered in the tropical Pacific which has an impact on climate and weather on a nearly global scale. Another regional climate influence is the North Atlantic Oscillation which can affect storm patterns over New England. We'll return to the ENSO phenomenon shortly.

As we have come to know from watching the evening weather on TV, high and low pressure systems, storms, and associated temperatures and precipitation patterns move rapidly across the United States (as well as the rest of the world) from west to east. Weather affecting the west coast soon affects us. Figure 2 shows that we are in the unenviable position of being down-wind from the rest of the country. Weather and climate are clearly large-scale and global processes. .

Our understanding of how the climate system works, although incomplete, has improved dramatically as a result of our venturing into space. Observing Earth from orbit has significantly improved our ability to predict storms and to monitor pressure systems as they move across the country. Weather satellites are now taken for granted, and our understanding of the processes that result in local weather patterns have greatly improved in the past 25 years.

Even though we have improved our technological capabilities and understanding of the climate system, scientists still cannot predict the weather and its long-term cousin, climate, with much accuracy. Two primary limitations in predicting weather and climate are related to the limited computing power and limited knowledge of regional factors affecting both weather and climate.

Additionally, significant variations in climate can and do occur naturally. Many of the factors affecting climate are beyond our control, such as incoming solar radiation and the relative areas of land and sea surfaces. These factors confound our understanding of human-induced climate change. However, other factors, such as the levels of greenhouse gases in the atmosphere and the amount and health of vegetation on land (and in particu-

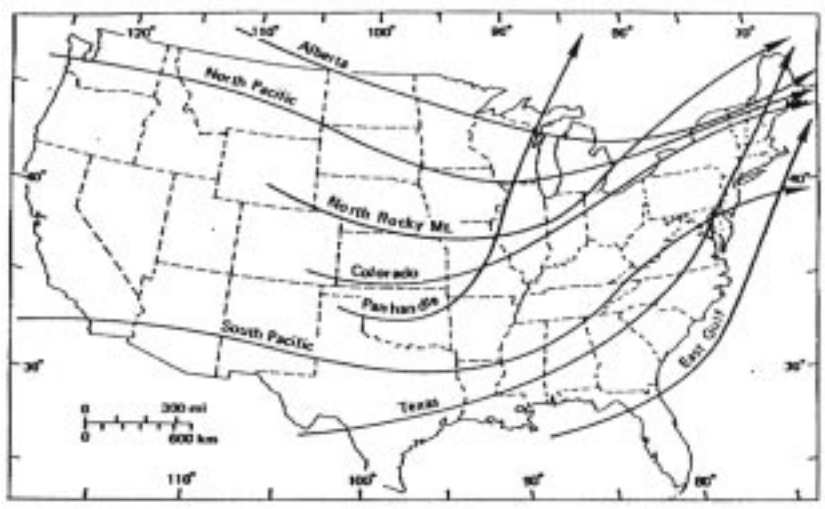

Figure 2. Major storm and airmass patterns for the United States shows that the Northeast's weather is intricately linked to weather phenomena in the rest of the nation and Canada. Additionally, this airmass pattern results in the Northeast receiving high concentrations of chemical airborne pollution from outside the New England region

lar, forest species) are directly related to our activities, and thus within our control.

Along with the oceans, the vegetation acts as a large CO_2 sink, removing CO_2 from the atmosphere as part of the process of photosynthesis. Human activity is destructive to woody vegetation by removal (deforestation) and by pollution-induced forest decline (Camels Hump in Vermont is a well-known example of spruce dieback due to high elevation acid mists). Trees and other vegetation act as CO_2 "sponges," soaking it up from the atmosphere and converting it to plant tissue and wood fiber in the form of cellulose. The large-scale loss of forested and other vegetated areas results in increased levels of CO_2 in the atmosphere.

Does El Niño-Southern Oscillation (ENSO) Affect New England Climate Patterns?

Believe it or not, our climate patterns of droughts and flooding here in New England have their origins in the equatorial Pacific. Scientists studying oceans and sea-surface temperatures have shown a strong linkage between sea-surface temperature patterns associated with the cyclical warming and cooling of waters off the coast of Peru to climatic patterns in North America. Since we are downwind from the rest of the country (Figure 2), what affects climate in North America, affects our region. Climate-related events such as extremely cold winters, summer-time droughts, heat waves and associated crop failures and forest fires, flooding, etc. result in higher heating/ cooling bills and higher food prices. In extreme cases, our homes and livelihoods may be threatened. We need to better understand these linkages, both to make better weather forecasts, and to develop coping strategies.

The El Niño phenomenon was first observed in the 1600s off the coast of Peru by fishermen who noticed a decline in the anchovy population during certain years. On an irregular basis, unusually warm waters off the coast around Christmas time were noted by the Peruvian fishermen. These warm water events were called El Niño (Spanish for "baby boy"), in reference to the Christ child. Only recently have we come to recognize that the development of an El Niño event actually originates in the western Pacific. A relaxation of trade winds in the Pacific results in an eastward movement of ocean currents along the equator, spreading warm sea-surface temperatures eastward toward the South American coast. The resulting El Niño is the warm extreme in year-to-year fluctuation of sea-surface temperature around the Galapagos Islands, while the cold extreme of this irregular cycle is called La Niña ("baby girl"). Together, this shift in winds plus the fluctuation between warm waters and cold waters off the coast of Peru is referred to as the El Niño-Southern Oscillation, or ENSO, for short.

In general, years dominated by an El Niño event will be characterized by hot summers, droughts and forest fires in North American, while La Niña years will typically have cool, wet summers, and spring and/or fall flooding. The ENSO events also may vary with season, so that the timing of specific effects (cold/hot, wet/dry) is more complicated than this simplified explanation. However, this simple explanation does demonstrate how our growing understanding of the connections between sea-surface temperatures in the Pacific and climate patterns in New England. This improved understanding will likely allow us to begin forecasting climate patterns 1-2 seasons in advance.

More specifically, researchers have determined several factors which affect North America and the Northeast due to ENSO. The Jet Steam path and storm fronts have been found to be related to ENSO. La Niña events are associated with chaotic winter weather in the Northeast. Additionally, researchers claim that ENSO is very powerful and can affect human populations around the world. In the Northeast it has been found to result in increased encephalitis outbreaks. Such findings can significantly impact our concern about regional climate variability.

It is interesting to note that hot, dry summers tend to be characterized by elevated levels of certain types of air pollutants, such as low-level ozone (tropospheric O_3) and sulfur dioxide (SO_2), while cool wet summers are characterized by better air quality. In this way, we can clearly see a connection between the physical climate and the chemical climate. Who would have guessed that ocean circulation patterns in the far-off Pacific would have such an impact on us in New England?

Do we have any control over the rates of greenhouse gas emission?

Figure 3 presents an example of how this has already been done. CFCs and other CFC-like compounds are greenhouse gases. They are better known as the major cause for ozone loss in the stratosphere. Figure 3 shows how levels of one specific CFC-like compound—methylchloroform (CH3CCl3)—exhibited significant increases in the atmosphere between 1978 and 1992. The increase of greenhouse gas compounds such as these is a result of their use in manufacturing processes and as refrigerants. The dramatic reversal by 1992 is

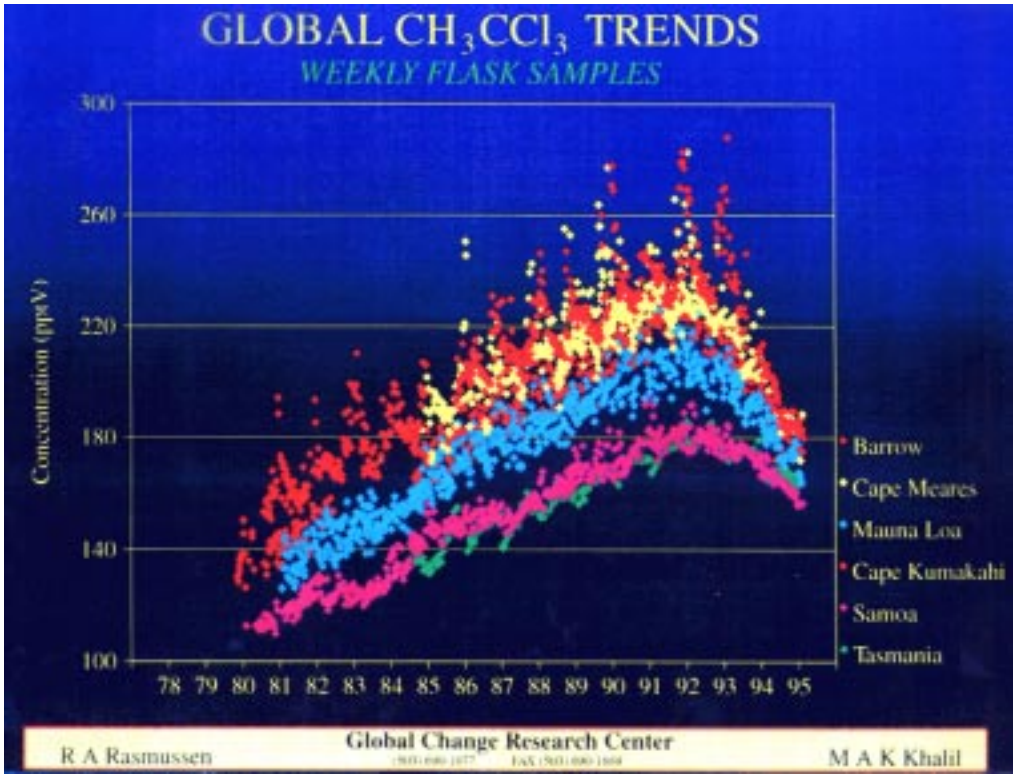

Figure 3. Global concentrations of a Freon-like compound, for selected collection sites from around the world. Increasing concentrations of compounds such as this one have been associated with their increased use in the manufacturing process and as a refrigerant during the 1970s and 80s. The decreasing trend in concentration starting around 1991-2 was measured following the enactment of the Montreal Protocol, which placed limits on the use of these types of compounds

the direct result of the Montreal Protocol initiated in 1987 and ratified by more than 150 countries by 1990. As a result of the Earth Summit held in 1992, the governments of the world agreed to totally phase-out production of this and many other CFC and CFC-like compounds. This dramatic change shows that a cooperative policy decision can have a profound influence on a global-scale problem. We just need to know the facts about an issue to construct a solution.

One way to control greenhouse gas effects is to reduce the amount reaching the upper atmosphere by storing carbon in land-based ecosystems. The change from carbon dioxide into oxygen and stored carbon is part of the photosynthetic process in plants. The forests of New England and New York contain 4.2 billion metric tons of carbon in forest ecosystems, and this amount is increasing at a rate of about 20 million metric tons per year. Annual CO_2 emissions in the United States, primarily from burning fossil fuels for energy, are equivalent to 1.5 billion metric tons of carbon. In the international negotiating arena, the United States is seeking ways to reduce or offset CO_2 emissions by 100 million metric tons, of which about 10 million would come from additional carbon storage in forests. The maturing forests of New York and New England are contributing in a very positive way to offset CO_2 emissions from other sources.

Are climate change issues relevant or important to the New England region?

Often when one thinks of climate change issues, it is easy to assume that these processes occur in distant places. We may think of tropical deforestation in Brazil or the thinning of the ozone layer above Antarctic. These are just examples of extreme events which catch our attention. We need to begin to realize that events in the New England region can both affect the regional and global climate and that the climate can impact the New England region.

According to the *World Almanac and Book of Facts, 1997,* among the largest industries in the New England region are energy, manufacturing and tourism. We need to begin to think about how climate change issues will impact our businesses, our health and our way of life. The following examples of climate change impacts on tourism, coastal/fisheries issues, and human health are meant to give a flavor of how relevant climate

change is to people of New England and upstate New York. These examples represent just the tip of the iceberg, and the workshop in September will focus on these and many more "stakeholder" concerns and issues.

Climate Change Impacts on Tourism in New England

Tourism is one of the largest industries in New England and upstate New York, and for many residents of this region it is a way of life. This multi-billion dollar enterprise is composed of many small businesses and mom-and-pop operations which give the defining character to the New England region. New England is unique in that it offers a wide variety of recreational and leisure activities for a vast population. This region's lakes and rivers, oceans and beaches, mountains, scenic towns, and natural areas are within only a few hours drive of the Boston-New York urban corridor, which hold a substantial percentage of the country's population.

The tourism industry and therefore the character of New England is vulnerable to the impacts of climate change. Weather and climate drive the tourism industry: if it rains during the summer, visitorship is down. If the snows don't fly and the temperatures are too high, the skiers and boarders don't head for the sky! New Hampshire Public Radio reported in June, 1997 that the popular 5-day Biker's Week event in New Hampshire's Lake Region resulted in $65 million in direct sales; that particular week was sunny and warm, with temperatures between 70-80ºF. If the event happened the following week, with the forecasts of rain and thunderstorms, dollar figures could be assured to have been lower. Weather forecasting and predictability are important to the New England tourism industry. If predictability decreases, temperature increases and rain and severe weather events increase, tourism is bound to take a direct hit. Understanding how these climate variables may change is important to our regional economy and well being.

Another issue of concern for tourism and the recreationalists is the chemical climate of New England and upper New York. An interstate panel of pollution and weather experts, headed by the EPA, recently stated that New York and New England are indeed downwind of the smog produced by mid-western states. This smog directly affects the regions prized by outdoor enthusiasts, especially at higher elevations. Air pollution is carried by the prevailing wind patterns until it intercepts forests on mountain sides facing a westerly direction. The haze produced not only affects mountain vistas but is believed to affect the health of people utilizing high elevation areas for recreational purposes. And, the ozone and acid mists impact the health of the forests in these regions as well. If the current trend of increased air pollution continues to occur, human health and the tourism industry will be broadly affected.

New England's fall foliage season is one of the biggest tourist draws to this area by out-of-staters. The beautiful colors associated with fall foliage are created by the unique mixture of tree species found within the Northeastern region, with maple being the most important. Yet, climate change predictions indicate that maple may be an affected species, causing delayed coloration, species collapse, or potential northern migration. Figure 4 shows two different model predictions of the future range of maple, based on a doubling of the current carbon dioxide concentrations. These scenarios predict a different pattern of maple migration, yet both show the northward shift. It is clear that a full understanding is lacking in the effect of climate change on forest migration, but preliminary indications insist that we consider the effects more

Another forest ecotype in jeopardy are the high elevation spruce and fir forests. Because these forests are located at high elevations they are already under several natural stresses in order to survive. Air pollution stresses further aggravate their chances of survival. Many studies have shown that dieback of these forests are related to pollution exposure, winter freeze injury (climate-related), or some combination of the two. Add into this equation climate variability and change and you add insult to injury!

The maple concern and the research documenting spruce/fir decline at high elevations are just two examples which become climate change issues for our region. Understanding climate change and how it will affect our natural areas and the tourism industry is important to protecting New England's heritage.

Allan Auclair and colleagues of the Science and Policy Associates have cited extreme weather events as important mechanisms for causing forest dieback in the Northeast. They predicted, using climate models and forest maturation ages for the Northeast, that major dieback of naturally occurring New England forest species such as birch, maple and spruce are likely to occur in the mid 21st century. This will not only have dramatic impacts on the tourism and forest products indus-

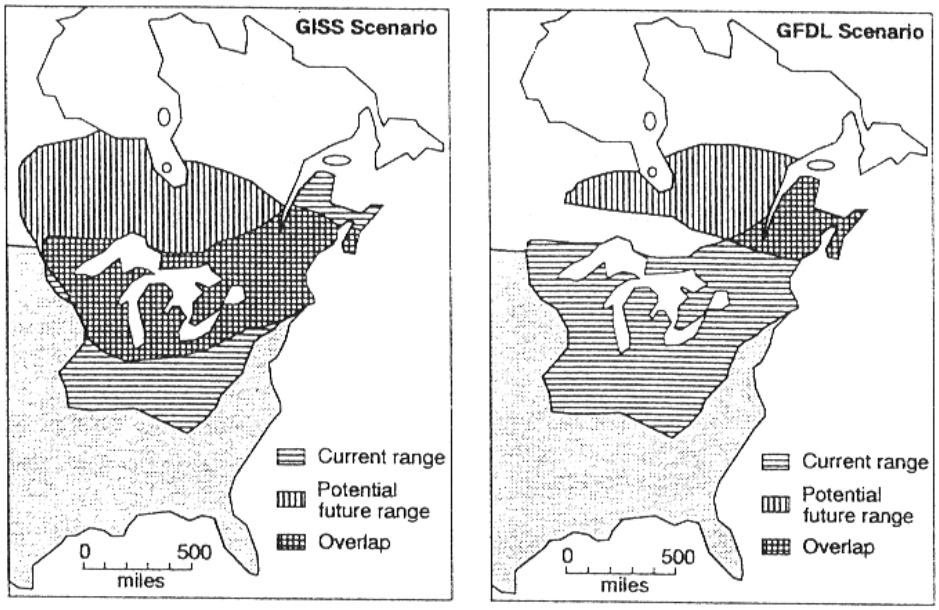

Figure 4. Two different models predict different ranges of sugar maple based on a doubling of atmospheric carbon dioxide concentrations. Yet, both predict a northern migration of the southern extent of maple distribution, with the GFDL model being most extreme.

tries but will mean a significant change in the way of life for children of the next two to three generations.

These issues are just examples of how climate change could affect one of New England's largest industries. The workshop being convened will solicit participant's input on their concerns regarding climate change effects on tourism and other issues. Much is still unknown regarding climate change and the particular effects on New England. Yet, it is important to begin now to address the issue of climate change.

Climate Change and Coastal and Fisheries Issues in New England

The decline of fisheries in the Northeast, where estimates of stocks of cod, haddock and yellowtail flounder are at historically low levels, has been blamed on overexploitation. All along the North Atlantic coast changes in species composition have also occurred, with less desirable species such as dogfish and skates replacing the once abundant groundfish stocks, mainly as a result of over-fishing. It is not clear at present how these declines may be related to climate change.

While there is still uncertainty in the connections between fisheries resources and climate change in the Northeast, researchers have shown that the present distribution of fish populations with water temperature can be used to estimate shifts in fish location resulting from climate change. El Niño-Southern Oscillation events which cause shifts in the ocean temperature have been shown to cause change is fish distribution. Some scientists believed that a change in water temperature kept cod from returning to Newfoundland waters in 1995.

Ocean researchers reported a 1 degree Celsius rise in both the mean and maximum water temperature in August between 1976 and 1996 over Jeffries Ledge, located off Cape Ann, Massachusetts. Increases in ocean temperature can result in northward migration of certain invertebrate species. Species such as the resilient and aggressive starfish (*Asterias forbesii*), found near the Isles of Shoals, off the coast of New Hampshire and Maine, have already been observed to be migrating north.

A recent and unusual outbreak of dense algae (an algal bloom occurred in March, 1997) turned Cape Cod Bay a murky brown, raising concerns about a disruption of the food supplies for the endangered Northern Right whales. This algal bloom appears to have been the cause of the whales abandoning their traditional feeding grounds this year at the earliest date ever recorded. Many of the 325 known remaining right whales, the most endangered of the world's large whales, typically spend the winter and early spring in Cape Cod Bay feeding on crustaceans called copepods. New calves in particular, need the spring copepod harvest to gain weight and strengthen prior to leaving the area. Most years the whales stay in the bay until late May. This year most of the whales were gone by late March.

Scientists know little about how the algae (genus *Phaeocystis*) affect the copepods that the whales eat. However, the coincidence between the algal bloom and the whales' early departure is a source of concern. Perhaps an even greater concern relates to the fact that a decline in copepods may signal a more general alarm for the health of the Cape Cod Bay ecosystem, and an alarm for the larger fish populations in Cape Cod Bay. A current knowledge gap exists in our full understanding of the impact that climate change (warming waters, changing water quality, etc.) will have on New England coastal resources.

Rising ocean temperatures and the accompanying expansion of the water itself contribute to sea level rise, as does more water entering the oceans via the melting of land-bound glaciers and ice sheets. Since the rebound of the earth's surface after the last glacier receded in New England 12,000 years ago has ended, sea level rise is a reality that all low-lying coastal areas must face.

Rising sea levels causes intertidal animals and plants to move to higher elevations. Salt marshes in New England, one of the most productive of the intertidal habitats, are relatively new—only about 4,000 years old. They persist partly due to a balancing act between the rate of sea level rise and the accumulation of sediments and plant material which together form peat on the marsh surface. It is uncertain whether this balance will continue with sea level rising faster in the past fifty years (1.8 mm or 0.07 inches per year) than the rate of rise during the past 2-3,000 years (1 mm or 0.04 inches per year). In addition, man-made structures such as culverts and roads restrict the tidal flow and limit the inland migration of marshes. This results in the replacement salt marsh plants by fresh-water species.

Salt marshes and estuaries provide food and shelter for 70% of the fish and shellfish in the ocean, at some point in their life. A rise in sea level and development-curtailed inland migration of all the intertidal habitats will affect abundance and biodiversity of many plant and animal populations that are essential to food chains that support upper trophic-level animals such as fish.

Storms also have a detrimental effect on some commercially important species. Excessive rainfall such as the 15 inches Great Bay estuary in New Hampshire received in 24 hours last September, caused death and migration of lobsters that traditionally inhabit the Bay, reducing this year's catch.

Economic hardship in coastal communities is beginning to result from climate change. In the past decade, several New England coastal communities have refused shoreline development such as tourist hotels on the basis of predicted increases in sea-level.

As the predicted duration and severity of storms develops, as it now seems to be doing, coastal property owners face increasing economic loses. Coastal New England is continuously exposed to dynamic and corrosive environments whose complexities are exacerbated by harsh winters, severe storms, great tidal ranges from 3 to 50-plus feet and a very irregular coastline. By the year 2010, 70% of New England's population will live within 50 miles of the coast, and more and more people will be directly affected by storm damage to their homes and commercial properties. Development of environmentally-sound technologies for existing and new applications for the New England coast are dependent upon improved ecological knowledge of the environment. Developing a better understanding of how climate change will impact this economically-significant region is most important.

The Impact of Climate Change on Human Health

When most people think of climate change issues and human health, they seldom go beyond the idea that the "ozone hole" allows more dangerous ultraviolet (UV) light to reach the surface of the Earth, and that this increased exposure to UV can cause skin cancer and glaucoma. They also assume that it is a problem for people living in Australia and New Zealand, but not here in New England. Dr. Paul Epstein, Associate Director of the Center for Health and the Global Environment, Harvard Medical School believes differently. He has written many general-purpose articles dealing with health and climate change (for example, the Op-ed article in the Boston Globe, April 10, 1997) and sees the New England area as likely to feel the impact of climate change in many aspects of human health.

Heat-related deaths in cities—which act as heat islands—will be exacerbated by warming, air pollution and smog (ground-level ozone), created both locally and up-wind (see Figure 2) of urban areas. These impacts, particularly with increased cloudiness (associated with the enhanced hydrological cycle), may even act synergistically (e.g., to increase ground-level ozone).

Moreover, the disproportionate rise in minimum temperatures (T_{min} or nighttime and winter temperatures) accompanying climate change means that less nighttime relief during heat waves, espe-

cially when there is a high heat index (a function of temperature and humidity). The humidity traps out-going radiation, decreases nighttime cooling, and exacerbates the impact on mortality.

A warmer atmosphere holds more moisture (6% more for every 1°C); and these changes may, in part, be attributable to the increased hydrological cycle and increasing cloudiness, reducing daytime warming and retarding nighttime cooling. Additionally, the disproportionate rise in T_{min} favors insect overwintering and activity. Researchers report that since 1950, maximum temperatures have risen at a rate of 0.88°C per 100 years, while T_{min} increased at a rate of 1.86°C per 100 years.

Infectious diseases may be increased due to climate change conditions (wetter, warmer summers, less severe winters) that promote tick, mosquito and rodent populations, populations which carry diseases such as Lyme Disease, Ehrlichiosis, Eastern Equine Encephalitis, Hantavirus, etc. Increased run-off of nitrogen and other nutrients into estuaries and bays, coupled with hotter summers (that promotes algal growth and favors the more toxic forms [cyanobacteria and dinoflagellates]) can lead to increased occurrence of red-tides and shellfish poisoning, brown-tides (lowering oxygen levels in water, harming seagrasses and shellfish beds), and can lead to increased diseases of shore birds, sea mammal, and fish.

Food-borne diseases such as toxic E. Coli, Salmonella, Cyclospora and Hepatitis-A may also be enhanced by warmer, moister conditions. Extreme weather events like flooding are particularly associated with outbreaks of Cryptosporidia and Giardia, protozoa that are not sensitive to chlorine.

In addition diseases of terrestrial plants and agricultural crops can be affected. Extreme weather events (flooding and prolonged droughts) increase the susceptibility of forests to infection. Presently, the woolly adalgid presents a threat to hemlock trees in New England; and stressful weather could exacerbate this problem.

Climate extremes are becoming more frequent, and they are also contribute to outbreaks of disease. Floods foster fungal growth and provide new breeding sites for mosquitoes; while droughts concentrate microorganisms, and encourage aphids, locust, whiteflies and—when interrupted by sudden rains—spur explosions of rodent populations. Because of the strong influence of climatic factors prediction of weather patterns based on ENSO and other climatic modes, plus regional patterns, may prove useful for anticipating conditions conducive to such "biological surprises" and epidemics.

These impacts on health could also have substantial economic impacts on our society. These range from the cost of health care to deal with the increased impacts to the costs of prevention measures, such as spraying to control insect populations. Environmental costs would be associated with many of the impacts, as well (consider insect spraying). Outbreaks of diseases can affect humans, agricultural crops and livestock; and their impacts can ripple through economies and cascade through societies. In 1991, for example, the cholera epidemic in Latin American cost Peru over $1 billion in seafood exports and lost tourist revenues. In 1994, the outbreak of plague in India (accompanied by malaria and dengue fever in the wake of widespread flooding) cut tourism precipitously and cost international airline and hotel chains from $2 to 5 billion.

Cruise boats are turning away from islands affected by dengue fever and other insect infestations, and coastal algal blooms along beaches. The consequences could be significant: The tourist industry in the Caribbean generates $12 billion annually and employs over 500,000 people.

The current resurgence of infectious diseases involving food, water, insect and rodent carriers can affect trade, transport, tourism and development. As the headline of Dr. Epstein's article stated: "Warm and wet conditions spell trouble for the world."

Where Do We Go From Here? What Do We Do?

It is easy to respond to the examples presented in this paper with a "gloom and doom" approach, giving a shrug of the shoulder and some nervous laughter. The difficult task at hand is to view these issues as both important and something that we need to know more about. We can't continue to ignore the early-warning signs of what the future will hold if human impacts on the regional and global climate go unchecked. As a people we are conducting a global experiment, the outcome of which we are currently unable to predict. We have records of the past, as well as sophisticated models to attempt projections, but what is currently missing is the local knowledge of the real concerns, perceived vulnerabilities, and the current state of knowledge among a broad range of stakeholders who will be directly impacted by climate change.

Using informed stakeholder input, policy makers and scientists can guide and conduct research

which will help us to understand better the climate change issues and their impacts. We need to also begin to look at the regional climate patterns and predictability in order to separate the natural climate variability from human induced climate changes. Recognizing that we currently lack a full understanding of the complex climate and earth systems, we need to accept the high possibility that our interactions with the environment can negatively impact our lives in the near and/or long-term future. By accepting this possibility we can begin to adapt some of our actions and policies in order to mitigate the magnitude of the potential impacts.

Awareness of the climate change issues is an important aspect to reducing the impacts of climate change in the future. We need to properly educate the people of our region on the current understanding of climate change and offer positive and active solutions to the problems. Ensuring that people of the New England/upstate New York region receive accurate information from the on going research and know how to process that information to increase their knowledge of the issues is fundamental. Developing educational outreach programs that engage citizens of all ages in a wide spectrum of thought, activities, and action in school programs, public forums, teacher education workshops, and the media are important for developing the kind of ethos and knowledge required to meet the challenge that climate change presents to our region.

The New England Regional Workshop will provide an ideal environment by beginning to develop an open dialogue among stakeholders, policymakers and research scientists. The U.S. Global Change Research Program needs your input. Please join us at the New England Climate Change Impacts Workshop, to be held at the University of New Hampshire from September 3-5, 1997.

The White Paper was developed for the New England Regional Climate Change Impacts Workshop, held at the New England Center on the University of New Hampshire campus, September 3-5, 1997. The White Paper was compiled and edited by Shannon Spencer and Barrett Rock, with contributions from members of the Steering Committee.